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ABUNDANCE, HABITAT USE, AND MOVEMENTS OF BLUE-WINGED MACAWS (*PRIMOLIUS MARACANA*) AND OTHER PARROTS IN AND AROUND AN ATLANTIC FOREST RESERVE

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ABSTRACT.—The Blue-winged Macaw (*Primolius maracana*) has disappeared from most of southern Brazil, Argentina, and Paraguay; its remaining southern stronghold is the 2,179-ha Caetetus Reserve, São Paulo state, Brazil. We estimated the macaw's population inside the reserve (88 individuals) and examined how it and other parrots use the extra-reserve landscape, which is dominated by coffee plantations and pasturelands. Flight activity of the macaw and Scaly-headed Parrot (*Pionus maximiliani*) declined with distance from Caetetus, although many macaws flew to the vicinity of the reserve to roost. Two other species, Canary-winged Parakeet (*Brotogeris versicolurus*) and White-eyed Parakeet (*Aratinga leucophthalmus*), used the landscape independent of the reserve itself. We recorded parrots in 90% of our 1-km^2 study plots outside (<12 km) the reserve, but no species was recorded using pasture, coffee or rubber/orange plantations, or scrub habitats, which composed 80% of the landscape around the reserve. Only four habitat types were used by any species. Primary and secondary forests were the habitats most preferred; *Eucalyptus* plantation habitat was the only totally anthropogenic habitat used. Clearly, protection, and preferably augmentation, of forest cover around Caetetus may be crucial for the macaw's survival at this important site. *Received 2 March 2004, accepted 11 January 2005.*

Habitat fragmentation has affected a multitude of taxa worldwide (e.g., Saunders et al. 1991, Turner 1996) by disrupting forest dynamics (Laurance et al. 1998) and adversely affecting floras and faunas (Alzen and Feinsinger 1994, Dale et al. 1994). Surprisingly, few studies have examined the effects of fragmentation on large frugivorous birds such as parrots, hornbills, and toucans. These birds are among the most threatened in the world (BirdLife International 2000) and often disappear from small fragments (e.g., Willis 1979). On the other hand, many are also highly mobile, which may allow them to disperse to areas within fragmented landscapes (e.g., Rowley 1983, McNally and Horrocks 2000).

The ability of a given species to use the mosaic of different habitats found outside of reserves (extra-reserve landscape) may affect its future survival, which makes this an important topic for research. Agro-ecosystems cover the vast majority of land outside protected areas (Western and Pearl 1989), which could have important influences on species ecology (Mesquita et al. 1999, Bentley et al. 2000) and survival (Laurance 1991, Gascon et al. 1999). A species' ability to use the extra-reserve landscape may be especially important around protected areas or other habitat fragments, as dispersal into the extra-reserve landscape might boost local populations (e.g., Ricketts et al. 2000). In the case of large avian frugivores, which tend to occur at low population densities (e.g., Marsden 1999), it is unknown whether protected areas can support viable populations of some taxa, especially in small reserves (e.g., Gurd et al. 2001). Examination of landscapes adjacent to reserves or other "key patches" (Verboom et al. 2001), and improving extra-reserve habitat suitability for threatened taxa, may be a first step toward enhancing populations in and around protected areas, or at least buffering within-reserve populations from negative outside influences (e.g., Gotmark et al. 2000).

The problem of forest fragmentation is acute in Brazil's Atlantic Forest, where remaining forest cover is ~7.5% of the original 1 million km^2 (Morellato and Haddad 2000, Myers et al. 2000). Deforestation has been particularly intense in the interior of São Paulo state; aside from the relatively large Morro do Diabo State Park, the few small fragments of forest that remain are isolated by vast areas of sugar cane and other agricultural land (e.g., Cullen et al. 2001). One of these fragments is

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the Caetetus Reserve (2,179 ha), situated near Garça. The reserve is surrounded by an extra-reserve landscape dominated by pasturelands and coffee plantations, but which also contains small areas of remnant and degraded forest, along with plantations of *Eucalyptus* spp. and citrus fruits. The reserve holds São Paulo's largest remaining population of the Blue-winged Macaw (*Primolius maracana*; formerly placed within *Ara* or *Propyrrhura* but now assigned to *Primolius*, Tavares et al. 2004), a species classified as "Vulnerable" (BirdLife International 2000). This species (body length = 39 cm) has disappeared from many of the protected areas in the southern part of its range (M. F. Nunes unpubl. data). Six other parrot species survive in the area (body lengths from Juniper and Parr 1998): White-eyed Parakeet (*Aratinga leucophthalmus*), 32 cm; Maroon-bellied Parakeet (*Pyrrhura frontalis*), 25–28 cm; Blue-winged Parrotlet (*Forpus xanthopterygius*), 12 cm; Canary-winged Parakeet (*Brotogeris versicolurus*), 25 cm; Scaly-headed Parrot (*Pionus maximiliani*), 27 cm; and Blue-fronted Parrot (*Amazona aestiva*), 37 cm.

Our objectives were to (1) estimate population sizes of Blue-winged Macaws and other parrot species within the reserve, (2) examine parrot use of the extra-reserve landscape, and (3) determine which features of the extra-reserve landscape influence parrot use. We then used these results to make a preliminary assessment of the likely viability of parrot populations in the area and to suggest which features of the landscape should be preserved or enhanced to protect parrots.

METHODS

Study area.—The study was based in and around Caetetus Ecological Station, São Paulo state, Brazil (22° 24′ S, 49° 42′ W; Fig. 1). The reserve covers 2,179 ha and consists mainly of mature, semi-deciduous forest (the area has been protected from major logging for ~30 years) and some areas of more recently disturbed secondary forest. Additionally, there are much smaller areas dominated by stands of bamboo and palmito (*Euterpe edulis*), and some small artificial lakes (Fig. 1). Annual precipitation averages 1,260 mm (Cullen et al. 2001). The study was conducted toward the end of the dry, cool season (May to September) in the plateau region of São Paulo. The landscape surrounding Caetetus is dominated by pasturelands and coffee plantations (Table 1), although fragments of degraded and regenerating forest and riverine forest also occur outside the reserve.

Within-reserve study.—We censused parrots in July and August 2001. The identification of parrot species, by both sight and call, and estimation of their distances from census points, was practiced for 10 days before starting the study. We established 90 parrot census points at 200-m intervals along nine transects. Caetetus has an existing network of narrow "research" trails covering much of the reserve and all points were placed along these trails (Fig. 1).

We sampled each census point six times—three times between 07:30 and 10:00 (UTC–03) and three times between 14:30 and 17:00—giving a total of 540 samples. Point counts commenced immediately upon reaching the point and lasted 5 min; any parrots observed close to the census point as the observer approached the station were also recorded. We recorded parrots within 50 m of the census point. For each parrot, we recorded the species, group size, whether it was flying or perched, the time it was seen or heard, and an estimate—or in some cases an actual measurement—of the distance from point to parrot.

Within a 40-m radius of each census point, we measured several habitat variables. We chose a 40-m rather than 50-m radius for ease of data collection and because only a small proportion of parrot records were expected at distances of 40–50 m away from the observer. We recorded the number of dead standing trees and the circumference at breast height of the five largest trees. Trees on which the first major branch was at or above half the tree's height were categorized as "primary-forest" trees, as they had probably grown under a full canopy. Trees branching below half their height, those with scars from dropped branches, or those showing vertical growth of branches near their base, were categorized as "secondary-forest" trees. The distance of each point to the nearest forest edge and the nearest river or lake was determined from Global Positioning System (GPS) coordinates and maps.

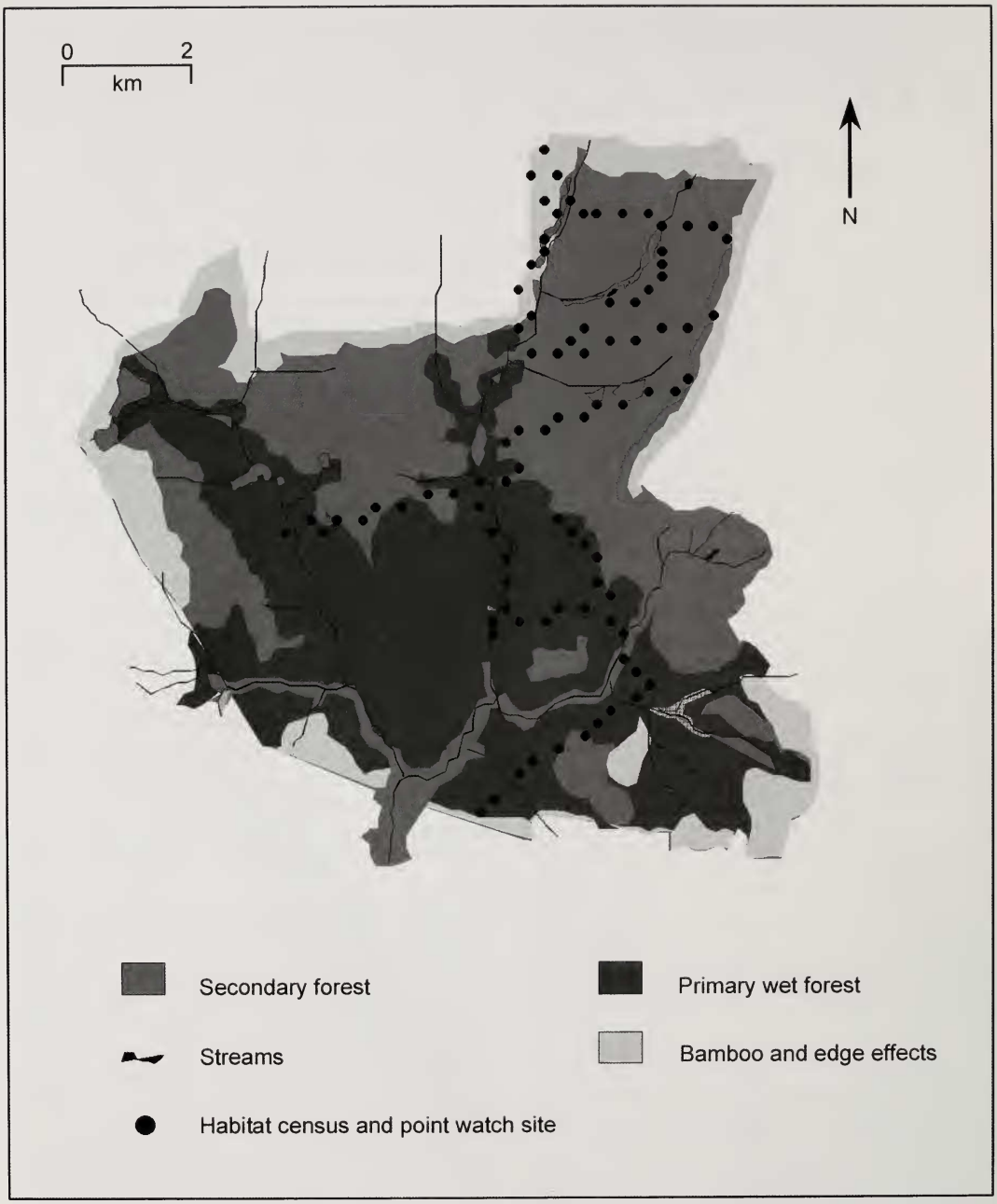

FIG. 1. Map of Caetetus Ecological Station, São Paulo state, Brazil, showing broad habitat types and census points within the reserve.

Extra-reserve study.—Habitat use and movements of parrots outside the reserve were studied in seventy 1- × 1-km plots located within a 12-km radius of the center of the Caetetus Reserve, thus composing 16.3% of the extra-reserve landscape within the 12-km-radius circle (Fig. 2). Thirty-five study plots were chosen randomly, then each was paired with a second, adjacent plot. Each pair of plots thus composed a 1- × 2-km rectangle

TABLE 1. Percentage cover and main vegetation types of habitats found in the extra-reserve landscape around Caetetus Ecological Station, São Paulo state, Brazil (2002).

Habitat type	Percentage cover	Dominant vegetation/species
Pasture	42.0	Various grass species
Coffee plantation	33.0	*Coffea* spp.
Riverine forest	8.0	*Calophyllum brasiliensis*
Primary forest	6.0	*Peroba* spp., *Talauma ovata*
Secondary forest	4.5	*Gallesia* spp., *Cecropia* spp.
Scrub	2.9	*Ormosia arborea*, *Cecropia* spp.
Eucalyptus plantation	2.1	*Eucalyptus* spp.
Rubber/orange plantation	1.1	*Hevea brasiliensis*, *Citrus* spp.

with the long axis facing (i.e., <45° from) the nearest part of the reserve (Fig. 2).

During July and August 2001, parrot movements and habitat use in each plot were recorded (one observer per plot) during one day between 07:00 and 10:30 and again between 15:00 and 17:30. Observer position within a plot was determined by the best view afforded of the plot (but all points were within 200 m of the plot's perimeter); because the landscape around Caetetus is gently rolling, it was possible to find points at which the view over each plot was practically complete. During each survey, we recorded the parrot species, group size, time of entry into the plot, flight direction, and type of habitat used.

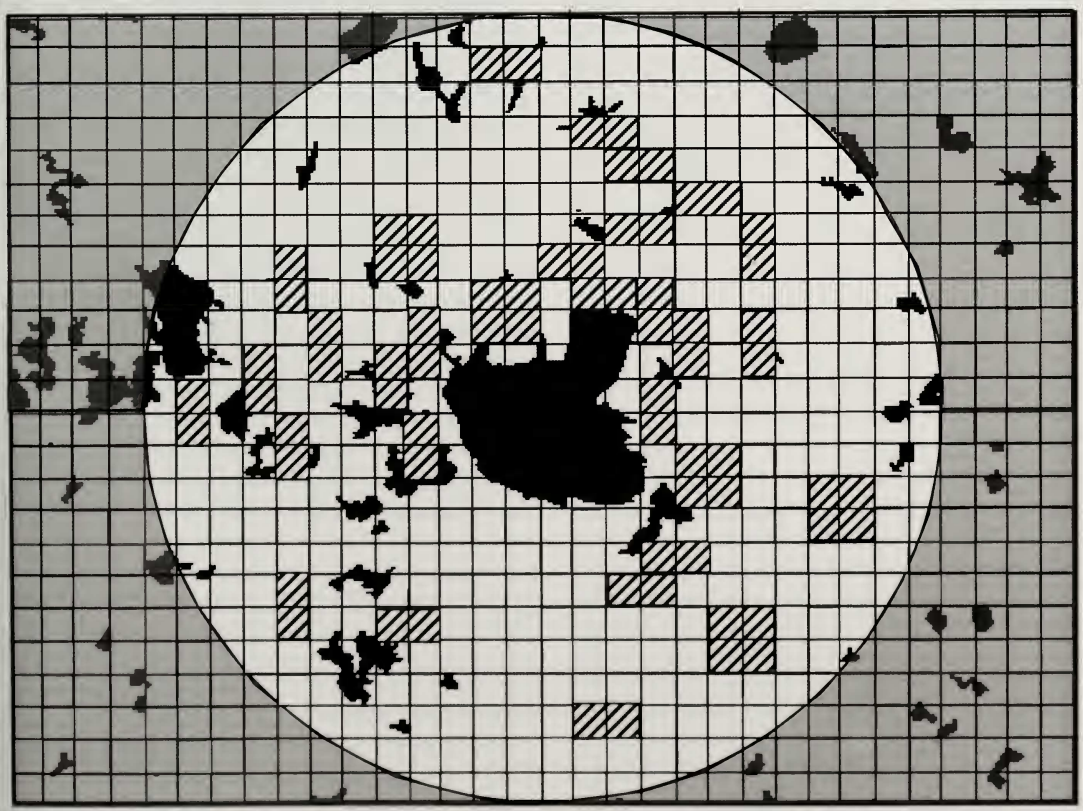

FIG. 2. The landscape around Caetetus Ecological Station, São Paulo state, Brazil. The circle represents the study area within 12 km of the center of the reserve. Also shown are 1- × 1-km study plots (hatched) and extra-reserve forest remnants (black). Areas in gray are outside the study area.

A vegetation survey was carried out in each square on the day of the parrot survey. Four 1,000-m transects were placed parallel to each other at 200, 400, 600, and 800 m across each plot, providing 4 km of transect per plot. One observer (BE) walked the transects, recording with a GPS the total length of each of 11 habitat types. Habitat types contributing >1% of total habitat measured are shown in Table 1; the other habitats were bamboo, marsh, and buildings. Natural forests were classified as primary forest if there was little evidence of disturbance and the canopy was closed (these areas were usually fenced off), or as secondary forest if there was evidence of much heavier disturbance (logging, fire, and grazing by cattle) and/or the canopy was discontinuous. We calculated a habitat-richness variable for each plot by summing the number of habitat types.

From digitized maps, we calculated three measures of connectivity between each plot and the Caetetus Reserve. Distance to the reserve (DIST) was calculated as the distance from the plot to the nearest edge of the reserve. Percentage of forested land between the plot and the reserve (FOREST) was calculated as the percentage of the DIST vector that transected natural forest (primary, secondary, or riverine forests). Finally, an index of forest gap (GAP) between the plot and the reserve was calculated as the greatest distance between adjacent areas of forest along the DIST vector, divided by DIST.

To determine whether extra-reserve habitats were geographically clumped (which could influence extra-reserve landscape use by parrots) and whether we could treat paired plots as independent of one another, we tested for spatial autocorrelation in habitat measures between paired plots. Specifically, we ascertained whether adjacent plots were more similar to each other than they were to randomly selected plots with respect to eight habitat/landscape variables: percent primary forest, secondary forest, scrub, pasture, coffee, and *Eucalyptus*, as well as DIST and FOREST. First, we calculated—for each variable—the difference between paired plots by subtracting the smaller value from the greater value. Second, we calculated this difference between one of the two original plots (randomly selected) and one of the other 68 plots (randomly selected). We then compared the paired and random differences using Wilcoxon signed ranks tests ($n = 70$).

Data analysis.—Three parrot species—Maroon-bellied Parakeet, Blue-winged Parrotlet, and Blue-fronted Parrot—composed only 1.2% of parrots recorded in the extra-reserve landscape and were excluded from data analysis. This left four species for analysis: Blue-winged Macaw, Scaly-headed Parrot, White-eyed Parakeet, and Canary-winged Parakeet. All four species were found outside the reserve, but only macaws and Scaly-headed Parrots were recorded at census points inside the reserve.

Habitat associations of parrots inside the reserve were examined by testing for differences between habitat/landscape variables at "positive" census stations (species present on any of the six surveys) and "negative" stations (species absent). We used independent *t*-tests for habitat variables that were normally distributed, and Mann-Whitney *U*-tests for those with non-normal distributions.

We used Program DISTANCE (Buckland et al. 2001) to calculate density estimates for the two species (Blue-winged Macaw and Scaly-headed Parrot) recorded in the reserve. Records were entered in clusters, and density estimates were based on mean group size unless size-bias regressions of group size against distance were significant at $P < 0.10$, in which case group size was adjusted by DISTANCE. Records of parrots in flight were excluded from the analysis, as aerial records clearly violate a key assumption of distance sampling (Marsden 1999). Data were converted to 4–5 bands for analysis. No right-hand truncation was used. Model selection and fit were assessed using the Akaike Information Criteria (AIC) minimization criterion and goodness-of-fit tests (Buckland et al. 2001). For both species, the pattern of detection best fit the uniform model with cosine adjustment. Density estimates were used in conjunction with the area of the reserve to produce estimates of total within-reserve population size.

To evaluate habitat use in the extra-reserve landscape, we analyzed records of birds in flight and records of birds that were perched. The flight direction of each bird in flight was classified as toward, away from, or parallel to the Caetetus Reserve. Chi-square tests were

TABLE 2. Positive (species present) and negative (species absent) habitat associations (mean ± SE) of perched parrots in Caetetus Reserve, São Paulo state, Brazil (2002). Boldfaced values are significantly different after sequential Bonferroni adjustment (*t*-tests were used for normally distributed variables; otherwise Mann-Whitney *U*-tests were used).

Habitat parameter	*Primolius maracana*		*Pionus maximiliani*	
	Present $n^a = 8$	Absent $n^a = 82$	Present $n^a = 26$	Absent $n^a = 64$
Distance from edge (m)	769 ± 470	909 ± 484	760 ± 398	952 ± 504
Distance from water (m)	306 ± 186	293 ± 209	252 ± 175	311 ± 217
No. dead standing trees	**1.6 ± 2.2**	**3.1 ± 2**[b]	2.9 ± 2.2	2.9 ± 1.9
No. primary forest trees	**4.6 ± 0.7**	**3.5 ± 1.4**[c]	3.7 ± 1.4	3.6 ± 1.4
Tree circumference (cm)	116 ± 17	135 ± 46	130 ± 43	135 ± 45
Circumference of largest tree (cm)	174 ± 42	214 ± 95	194 ± 90	217 ± 92

[a] Number of point count stations.
[b] $P = 0.039$, Mann-Whitney *U*-test = 185.
[c] $P = 0.016$, Mann-Whitney *U*-test = 163.5.

used to examine differences in flight directions of each species during the mornings and afternoons. Diurnal patterns of flight activity and habitat use were assessed by plotting the mean numbers of each species flying or perched per hr per km^2 during each hour of the morning (07:00–10:00) and afternoon survey periods (15:30–17:30).

Spearman's rank analyses were used to identify correlations between pairs of species in terms of how they used the 70 plots. In all multiple comparisons, we used a sequential Bonferroni adjustment (Rice 1989) to determine significance of individual correlations. Spearman's rank analyses also were used to identify correlations between the amount of flight activity and extra-reserve habitat type, richness, and connectivity measures. In effect, we looked for correlations between the number of flights made by parrot groups per hour across plots and the habitat or connectivity characteristics of those plots (e.g., percentage cover of each habitat type, distance to reserve).

To calculate a habitat preference index for each parrot species, we compared the proportion of perched parrot records (whether singly or in groups) in a given habitat type to the total percentage of that habitat type. For example, if 10% of perched records of a species were recorded in a habitat that composed 10% of the total vegetation across all plots, then the index of usage would equal 1. Values >1 indicated habitat selection, and <1 indicated habitat avoidance. Zero indicated habitats never used.

RESULTS

Habitat use and abundance within the reserve.—Although four parrot species were recorded in or flying over the reserve, *B. versicolurus* and *F. xanthopterygius* were only occasionally recorded. The two regularly recorded species, *P. maracana* and *P. maximiliani*, were neither positively nor negatively associated ($\chi^2 = 0.02$, df = 1, $P = 0.88$) with one another.

The presence of perched *P. maracana* at census points was negatively associated with the number of dead standing trees, and positively associated with the number of primary forest trees (Table 2). *P. maximiliani* showed no significant relationships with any of the habitat variables.

We recorded only 35 perched parrots during 540 point counts ($n = 11$ for *P. maracana*, and $n = 24$ for *P. maximiliani*). However, because these data represent only those parrots detected within 50 m of census points, density estimates were still reasonably high. The density estimate for *P. maximiliani* (8.8 + 2.0 per km^2) was approximately twice that of *P. maracana* (4.1 + 1.6 per km^2). The population estimate for *P. maracana* was 88 + 34 individuals (Table 3).

The extra-reserve habitat and its use by parrots.—Pasturelands and coffee plantations were the predominant habitat types, composing 75% of the extra-reserve landscape. Riverine and primary forests were the dominant natural habitats, but represented only 14% of the area. Natural habitats made up 21.4% of the extra-reserve landscape (Table 1).

TABLE 3. Encounter rates (groups encountered/10 point counts), density estimates (individuals/km^2), and population estimates for parrots in Caetetus Reserve, São Paulo state, Brazil (2002). Values are means ± SE (upper and lower 95% CI).

	Primolius maracana	*Pionus maximiliani*
Number of groups (*n*)	11	24
Number of point counts (*K*)	540	540
Encounter rate	0.20 ± 0.08	0.44 ± 0.10
Density estimate	4.1 ± 1.6 (1.9–8.5)	8.8 ± 2.0 (5.7–14)
Population estimate	88 ± 34 (42–185)	193 ± 44 (123–301)

P. maracana and *B. versicolurus* were the two most frequently recorded species (Table 4). Use of extra-reserve habitats by *P. maracana* was positively correlated with that of both *P. maximiliani* and *B. versicolurus*. Use of extra-reserve habitats by *B. versicolurus* was positively correlated with that of all other species.

Of the eight habitat/landscape variables tested, only DIST showed significant autocorrelation between plots ($Z = 5.02$, $P < 0.001$); this is not surprising, as adjacent plots were nearly equidistant from the reserve. Neither FOREST ($Z = 0.60$, $P = 0.55$) nor any of the habitat variables were autocorrelated: primary forest ($Z = 1.50$, $P = 0.13$), secondary forest ($Z = 0.72$, $P = 0.47$), scrub ($Z = 0.36$, $P = 0.72$), *Eucalyptus* ($Z = 0.75$, $P = 0.46$), coffee ($Z = 1.41$, $P = 0.16$), or pasture ($Z = 1.8$, $P = 0.072$).

Extra-reserve activity and movements.— Extra-reserve flight activity of *P. maracana* and *P. maximiliani* was greater in the mornings and evenings than during the middle of the day (Fig. 3A, B), whereas *B. versicolurus* exhibited greater flight activity in the early mornings (Fig. 3C). There were more records of perched *P. maracana* early in the mornings (Fig. 3D), whereas perched *B. versicolurus* were recorded more often in the afternoons (Fig. 3F).

Direction of *P. maracana* flight (the number of groups flying toward, away from, or parallel to the reserve) differed between the morning and afternoon ($\chi^2 = 29.2$, df = 2, $P < 0.001$). More birds flew away from the reserve in the morning, and more flew toward the reserve in the evenings than expected (numbers of parrots flying in other directions were similar in the mornings and evenings). There was no difference in the direction of morning and evening flights for *P. maximiliani* ($\chi^2 = 0.77$, df = 2, $P = 0.68$) or for *B. versicolurus* ($\chi^2 = 3.76$, df = 2, $P = 0.15$).

Factors influencing parrot movements.— Flight activity of *P. maracana* and *P. maximiliani* outside the reserve decreased with increasing DIST; however, none of the other connectivity variables were correlated with parrot movements (Table 5). Parrot groups of three species were recorded flying more frequently over plots containing relatively large percentages of natural habitats (primary, secondary and riverine forest, and scrub). Flight

TABLE 4. Parrot use of 1- × 1-km plots outside the Caetetus Reserve ($n = 70$ plots in all cases), São Paulo state, Brazil (2002). Associations between species are based on Spearman's rank correlation analyses of abundance of perched groups within plots. Spearman's coefficients are given for significant ($P < 0.05$) correlations after a sequential Bonferroni adjustment.

	No. groups		% 1- × 1-km plots		Correlations		
	F[a]	P[a]	F	P[a]	*Pionus maximiliani*	*Aratinga leucophthalmus*	*Brotogeris versicolurus*
Primolius maracana	249	41	86	27	+0.40	NS[b]	+0.50
Pionus maximiliani	142	25	44	16		NS[b]	+0.35
Aratinga leucophthalmus	9	15	7	4			+0.45
Brotogeris versicolurus	234	60	67	21			

[a] F = flying record, P = perched record.
[b] NS = not significant.

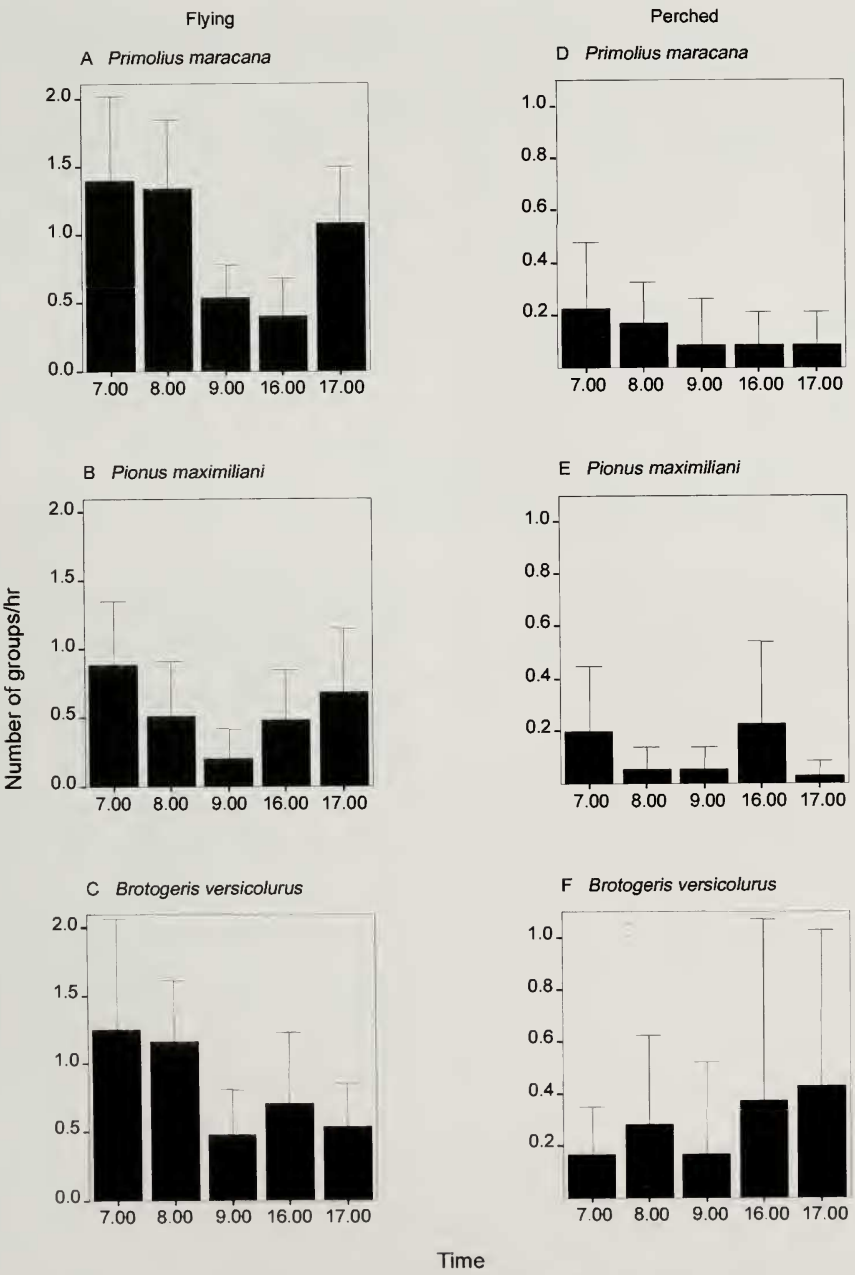

FIG. 3. Diurnal extra-reserve flight activity and habitat use (perched) for three commonly recorded parrot species at Caetetus Reserve, São Paulo state, Brazil. Bars represent the mean number of groups recorded per hour (mean ± SE) within hour-long time periods.

frequency of *A. leucophthalmus* was positively correlated with habitat richness within plots.

Extra-reserve habitat use.—Only four of the extra-reserve habitats were used by parrots, and the two dominant habitats—pasturelands and coffee plantations—were never used by any species (Table 6). The only artificial habitat used was *Eucalyptus* plantation (by two species). Primary forest was the habitat most preferred for *P. maracana* and *P. maximiliani*, whereas secondary forest was pre-

TABLE 5. Spearman's correlations ($P < 0.05$ after sequential Bonferroni adjustment; $n = 70$ plots in all cases) between frequency of flights by parrot groups over 1- × 1-km plots and characteristics of 1- × 1-km plots at Caetetus Reserve, São Paulo state, Brazil (2002).

Habitat/landscape variable	*Primolius maracana*	*Pionus maximiliani*	*Aratinga leucophthalmus*	*Brotogeris versicolurus*
Pasture	—	+0.36	—	—
Secondary forest	—	—	—	—
Coffee	—	—	—	—
Natural habitats				
Primary forest	−0.31	+0.35	—	—
Riverine forest	—	—	—	+0.27
Scrub	—	—	—	+0.38
Habitat richness	—	—	+0.27	—
Connectivity variables				
Distance to reserve (DIST)	−0.35	−0.58	—	—
Percentage forest between plot and reserve (FOREST)	—	—	—	—
Largest gap in forest between plot and reserve (GAP)	—	—	—	—

ferred by *A. leucophthalmus* and *B. versicolurus*. Riverine habitats were used by all species, but were not used disproportionately to their availability by any species.

DISCUSSION

Of seven parrot species recorded during our study, only two were regularly encountered in the reserve itself. *B. versicolurus* was recorded flying over and using a variety of habitats in the extra-reserve landscape (particularly those around farms), reflecting its generalist lifestyle (Juniper and Parr 1998). Movements of *A. leucophthalmus* were actually more common well away from the reserve, indicating some avoidance of habitats around the main forest block. Both of these species are thriving in Brazil's anthropogenic habitats (Juniper and Parr 1998).

The species we were most interested in, *P. maracana*, was frequently recorded both inside and outside the reserve. We could find few specific habitat associations for the species within the reserve, although it did tend to occur in areas of primary forest with few dead trees. Our population estimate for the reserve was 88 birds; however, for two reasons we believe that there are additional populations that spend much or all of their time outside the reserve. First, the within-reserve density estimate was based on data collected during the day at times when some individuals had left the reserve to feed in the surrounding agricultural landscape. Second, we believe that

TABLE 6. Preference index for parrot use of extra-reserve habitats outside Caetetus Reserve, São Paulo state, Brazil (2002). Habitats are ranked according to their use by *Primolius maracana*. Indices are based on the number of birds recorded as perched in the different habitats.

	Habitat preference index			
Habitat (%)[a]	*Primolius maracana*	*Pionus maximiliani*	*Aratinga leucophthalmus*	*Brotogeris versicolurus*
Primary forest (6.0)	3.8	2.7	0.3	2.3
Eucalyptus (2.1)	2.9	1.0	0	0
Secondary forest (4.5)	2.0	0.7	2.2	12
Riverine (8.0)	0.6	0.3	0.6	0.1
Pasture (42.0)	0	0	0	0
Coffee (33.0)	0	0	0	0
Scrub (2.9)	0	0	0	0
Rubber/orange (1.1)	0	0	0	0

[a] Percent of total extra-reserve habitat.

there is a population of *P. maracana* based well outside the reserve, as a flock of 56 individuals was recorded 9 km south of the reserve. These populations may be large enough for the species to persist in the area, at least in the short term.

Despite being recorded commonly outside the reserve, all four common parrot species were selective as to the extra-reserve habitats they used. The dominant habitats—pasture and coffee plantations—were never used by any species. This is not surprising, as the pasture and coffee crops around Caetetus contained very few remnant or planted trees. Coffee fruits may be used by *P. maracana* at some times of year (e.g., Marsden et al. 2000), but certainly coffee plantations are not attractive or a keystone habitat for any of the parrots. All records of parrot habitat use were in just four habitats, with *Eucalyptus* plantations being the only artificial habitat used. In fact, parrots only selected three habitats more than expected on the basis of their availability in the landscape: secondary forest was selected by three species, primary forest remnants by two species, and *Eucalyptus* plantations by one species.

Studies elsewhere have stressed the importance of dispersal ability and corridors for the use of extra-reserve habitats by animals (e.g., Pires et al. 2002). We calculated three habitat connectivity indices, but only one (DIST) was important in explaining patterns of parrot movements. It may be that the other measures did not reflect barriers to parrot movement, or at least did not add to the explanatory power of using simple distance from the reserve. *P. maracana*—like most, but not all parrots (e.g., Rowley 1983, Marsden et al. 2000)—are regarded as good dispersers, and we suggest that availability of natural forest, rather than mobility, constrains parrot distribution around Caetetus.

Blue-winged Macaws were once found in many states in Brazil, eastern Paraguay, and northeastern Argentina (Juniper and Parr 1998), but the species has become extirpated over much of its range, and further extirpations are predicted in forest fragments (Snyder et al. 2000). Although we do not know what limits the area's populations of parrots, there is general concern about recruitment rates among cavity-nesting parrots (e.g., Mawson and Long 1994, Snyder et al. 2000), and nest-site availability within the reserve needs to be examined. At a landscape scale, the maintenance of forest remnants around the reserve is most important to the populations of *P. maracana* and other parrots. We suggest that while primary forest may be most preferred by *P. maracana*, other forest types, and even *Eucalyptus*, has some benefit to the parrot assemblage.

Legislation in São Paulo state dictates that 10% of land on private farms be maintained as forest. Our data indicate that for Caetetus, as suggested for other reserves in the Atlantic Forest (Marsden et al. 2000), reforestation in areas adjacent to nature reserves may be disproportionately valuable for enhancing parrot populations, and, presumably, other wildlife that inhabit reserves. The degree of deforestation in the interior of São Paulo is so acute that there is a strong argument for focusing forest-restoration programs almost entirely on landscapes surrounding the region's few reserves.

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